ARS 42-65
August 1962

FARM BUILDING PANELS

A Research Report on Developing and Evaluating An Insulated Concrete Stressed-Skin Panel

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

This research report presents a pictorial account of the steps involved in developing a new type of insulated concrete stressed-skin panel suitable for farm construction. The panel, a combination of a thin mortar skin with newer insulation materials, may be useful in farm service buildings.

The experiments reported in this publication were performed both at the USDA Agricultural Research Center, Beltsville, Md., and at the Virginia Agricultural Experiment Station, Blacksburg, Va.

Prepared in

Agricultural Engineering Research Division
Agricultural Research Service
U. S. Department of Agriculture

FARM BUILDING PANELS

A Research Report on Developing and Evaluating an Insulated Concrete Stressed-Skin Panel[1]

By T. E. Kent, N. C. Teter, and R. C. Liu[2]

INTRODUCTION

Mechanization and rapidly changing agricultural practices require farm buildings that are versatile in function and economical to construct. The cost of on-site labor for conventional construction continues to increase, thus forcing more and more prospective purchasers of buildings to investigate the comparative cost of prefabricated structures.

The great advantage of prefabricated components is inherent in their manufacture under controlled environment. Too, unskilled labor can be employed both in the manufacturing and erecting of such building components. Lending agencies may be less reluctant to finance buildings that can be repossessed, much as an automobile. Also, properly designed prefabricated buildings can be erected quickly when shelter is needed and can be relocated to the best advantage when desirable.

Although a number of prefabricated curtain wall panels are available, they usually are unsuited for farm buildings. Such panels, often designed for pleasing appearance, are unnecessarily expensive. Low-cost panels adaptable to farm buildings would be desirable.

OBJECTIVES AND DESIGN CRITERIA

Research on materials and methods of constructing farm buildings inevitably led many engineers into projects for investigating the practicality of prefabrication. Agricultural engineers have studied many aspects of panelized construction, including building panels of plywood, hardboard, metal, and concrete.

This publication describes a study of an insulated concrete stressed-skin sandwich panel believed to be unique in some of its properties and applications.

---

[1] Cooperative investigations of the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Virginia Agricultural Experiment Station.

[2] Agricultural Engineers, Livestock Engineering and Farm Structures Research Branch, A.E.R.D., A.R.S., U.S.D.A., at Virginia Agricultural Experiment Station, Blacksburg, Va., Agricultural Research Center, Beltsville, Md., respectively.

The overall objective of this investigation was to develop a building panel having the following properties:

- Low cost, consistent with other objectives.
- Light enough to be erected without the aid of construction machinery.
- A minimum of 20 years expected usable panel life.
- Panel surfaces easily cleaned and disinfected for best use in food preparation plants and livestock housing units.
- Panels possessing sufficient insulating properties for livestock housing structures.
- Panels adaptable to as many building sizes, shapes, and types as possible--consistent with other criteria.

With these objectives established, the authors decided to develop a panel of portland-cement mortar cast around a semirigid insulating core.

DEVELOPMENT

After studying many plans of livestock structures and, where necessary, adjusting the established objectives noted above, the authors selected the panel dimensions to be 8 feet long, 2 feet wide, and 3 inches thick. These panels were to be fastened horizontally to load bearing columns. By much trial and testing a method of prestretching the reinforcing wires for accurate placement and for relief of curing stress was adapted. A pictorial account of the casting, testing, and erecting of these panels is presented.

COST OF MATERIALS

The expanded polystyrene or foamed glass used as a panel core costs about $0.12 a board foot (retail) or about $0.24 per square foot of panel. The 14-guage reinforcing wire costs about $0.03 per square foot. Thus, total retail cost <u>of materials</u> is about $0.30 per square foot. Volume purchase of these materials should result in a cost of about $0.20. No estimate of the cost of an automated casting plant can be made at this time.

If we estimate the cost of a concrete block wall, in place, at about $0.55 per square foot, it appears that the in-place cost of these panels can be made competitive with a block wall. Thus, for approximately the price of a block wall we might obtain a much stronger, more attractive, smoother interior finish and a better insulated wall.

CONCLUSIONS

The curtain wall panel made by encasing semirigid insulation between one-half inch mortar faces reinforced with prestretched 14-gage wire is better adapted to manufacturing in a plant similar to a concrete block plant than to home manufacturing.

Structural strength tests revealed this panel to be amply strong.

Plain butt joints calked with commercial compounds appears to be the most desirable of the joints tested in assemblies of building walls.

Prestretched mild steel reinforcing in the mortar faces imparts unusual strength and flexibility to the mortar.

SUMMARY

This publication shows pictorially some of the steps taken in developing and evaluating a curtain wall panel 2 feet wide and 8 feet long. Expanded polystyrene insulation, 2 inches thick, is encased between two faces of 1/2 inch mortar that is reinforced with prestretched 14-gage mild steel wire placed 1 inch on center. The inner face cast against polyethylene cures with a slick, sanitary finish. Tests of the panels for bending and for shear and resistance to impact, showed that the panels are adequately strong for any ordinary wall construction. Plain butt joints between erected panels resist water penetration as well as any joints tested. Use of calking compound in the joints gave better results than the use of mortar. The costs of materials for the panels amount to about $0.30 per square foot at present retail rates. It is concluded that these panels exhibit very desirable characteristics for farm construction, making them potentially a marketable building component.

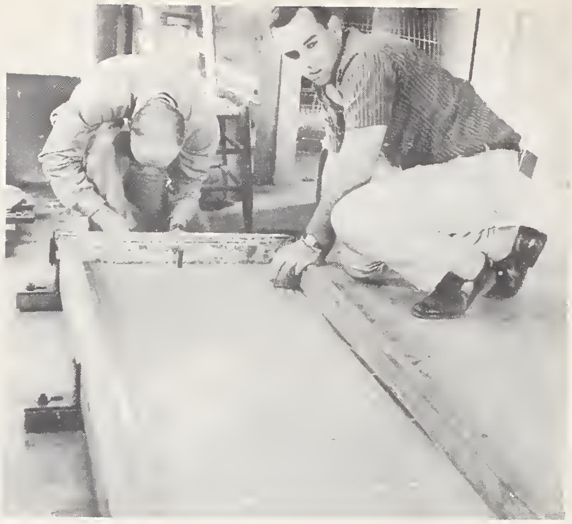
ACKNOWLEDGMENTS

The following companies[3] or associations furnished advice and materials: Colcrete Structures, Inc.; Dow Chemical; Koppers Co., Inc.; Pittsburg Plate Glass Co.; Portland Cement Association; and U. S. Steel Corp., American Steel and Wire Division.

---

[3] Mention of these firms does not constitute endorsement of their products by the U. S. Department of Agriculture over similar firms or products not mentioned.

Cement martar--ane part cement ta three parts well-graded sand--was mixed mechanically in a rotary mixer. Sufficient water, 7 gallons per bag af cement, was added ta make a stiff graut.



Galvanized welded wire reinfarcing (14 gauge, 1"x 8" mesh) was threaded inta mechanical jacks an each end af the panel farm. The battom surface of the panel was cast against palyethylene--caated paper, which gave a very smaath, almast slick, interiar panel surface.

Reinfarcing wire was prestretched priar ta casting martar. This stretching farce held the wire within the ane-half inch martar. The release af the wire after partial curing relieved curing tensile stresses, which resulted in a thin martar sectian with unusual strength praperties.

Mixed mortar was placed in the form. A screed and trawel were used ta obtain the necessary dimensianal accuracy.

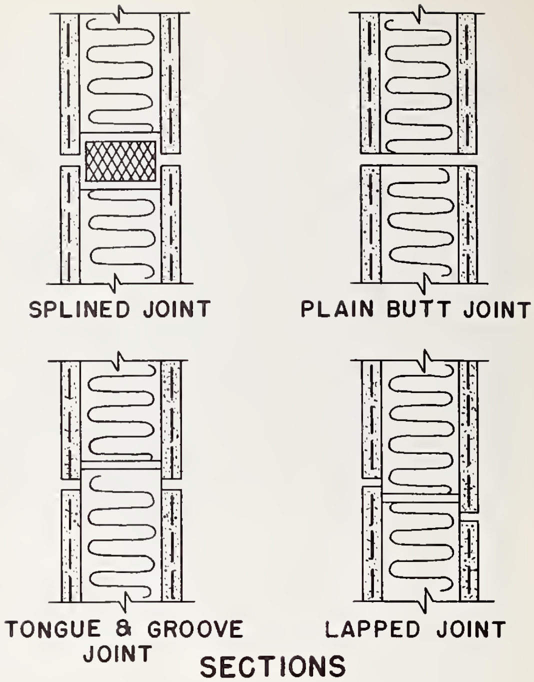
Vibration of the lower panel surface resulted in a very smooth surface with few air bubble voids. Panels were cast both with vibration and without vibration. By exercising care, smooth surfaces were obtained without vibration.

A precut core of expanded polystyrene placed above the lower panel surface had twelve 1-inch holes cut through to permit casting mortar shear resisters at strategic locations. Each corner of the core was rounded to permit these corners to fill with mortar to reduce panel handling damage.

Welded wire reinforcing was then stretched for the top or outside surface of the panel. Each shear resister was also reinforced. (Note the 1/2" x 3" pipe cast in each end of the panel. These are useful for erection.)

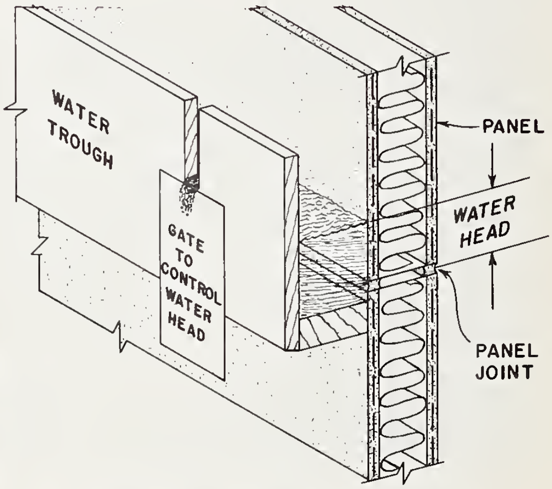
Finishing touches were applied with screed and trowel. Panels were then wrapped in plastic film and allowed to cure about 3 days at 70° F. After curing in the form, the wires were released. The panel was removed from the form, sprinkled with water, and rewrapped in film. This stage of curing lasted at least 1 week.

One of the objectives wos the development of a ponel light enough to be erected by two men. This panel weighs about 200 pounds.



Studies of the woter infiltration resistance of four joint configurations were conducted.

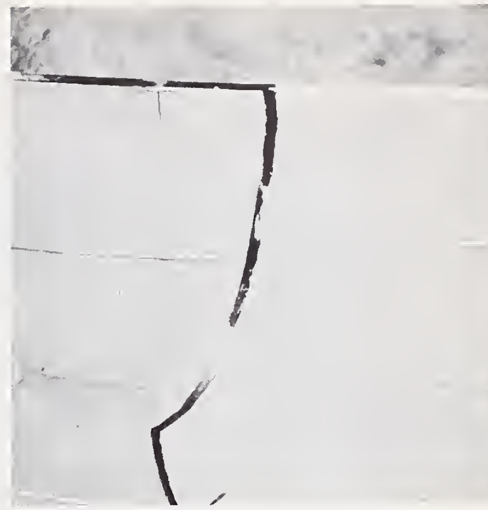
The use of o garden sproy hose under high pressure on these joints did not result in a comparotive evaluation, because none of these joints leaked under this spray.



TESTS FOR JOINT LEAKAGE

Joints were evoluated by a system of troughs through which water was continually circuloted. Adjustable gates at the far end permitted the application of a predetermined water head against the panel joints.

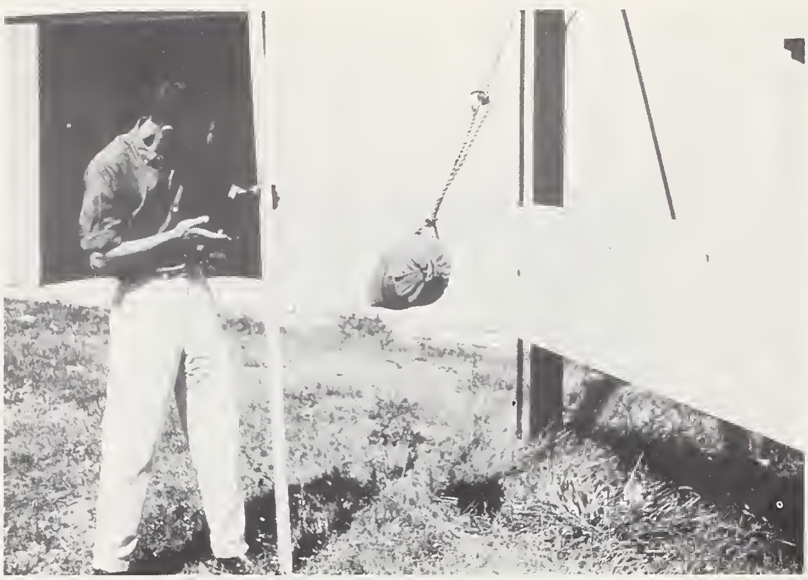
Sufficient water pressure always resulted in leakage of panel joints as shown by dark streaks. Resistance to infiltration was generally equal to the differential height of the joint. The addition of oil-based calk increased this resistance by at least 2 inches of hydrostatic pressure.



To determine the fire resistance of panels in a wall, a panel was broken. The openings were cut into it and ignited. Although expanded polystyrene is flammable, the fire tended to be self-extinguishing.

Load tests were conducted on eight representative panels. To simulate a uniform wind load, 50-pound sandbags were applied at quarter points. All panels carried a 42-pound per square foot equivalent uniform load. Some panels carried an equivalent 60-pound load. Deflections were continuously recorded.

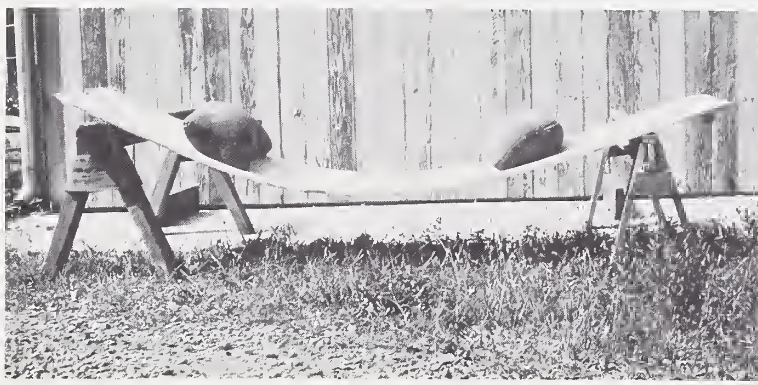
All panels tested failed in shear. Even after failure, no cracks were found in the tensile face. The panel shown is one which has been broken in shear and the core removed to investigate more precisely the areas of failure. An application for a private patent has been made for rights to the idea of shear connection between faces.



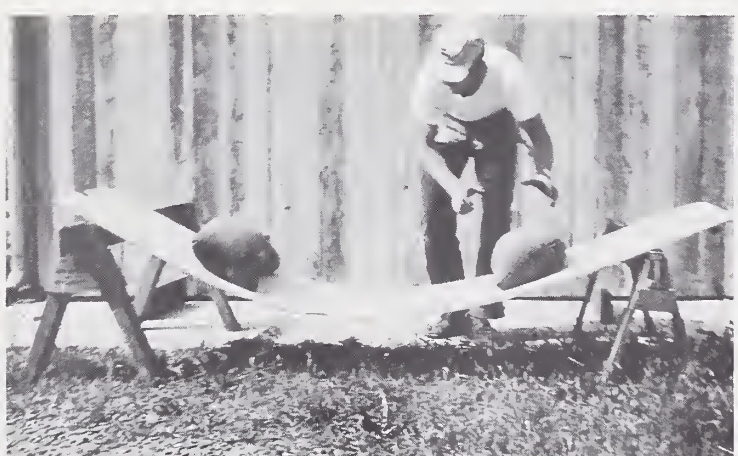
Studies of the resistance to impact were made, because these panels might be subjected to impact from animals, farm equipment, transportation, and erection. A 50-pound sandbag was released from varying heights and permitted to strike the midpoint of the panel.

Impact failures at increasing energy increments were as follows:

Energy ft.-lbs.	Effect
125	Shear failure.
175	Cracks in panel face.
225	Complete failure, as shown.



One "face" of a panel that had failed in shear is shown. The deflection of this "face" is about one-eighth the span. Span is 6 feet and measured deflection, 9 inches.



Additional increments of loading on the "face" resulted in deflection of about 8 inches more, making a total deflection of about one-fifth of the span. This flexibility is comparable to such materials as plywood.

A building of these panels was considered desirable for construction evaluation. The structural frame for this building consisted of pressure treated rectangular posts.

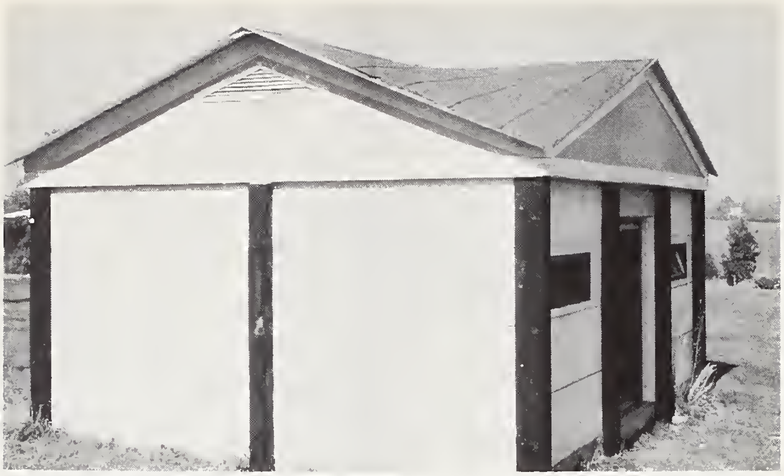
A grade beam from post to post was cast, perimeter insulation placed, and a floor slab cast. Workmen are completing the finishing of the grade beams and floor slab.

Panels were placed in a bed of mortar as shown. Subsequent panels were joined in this structure by mortar joints.

After plocing the ponel in its mortor bed, o leod hole was bored for o 1/2" x 6" lag screw. Corners were formed by bolting ponels ta o 2" x 10" thot wos fostened ta the post and by fostening other ponels to corner posts with lag screws.

After ponels were tastened in ploce, eoch joint wos tooled. (Further research is in progress on the use of synthetic mortors for horizontol joining.)

The structure is essentiolly complete. Workmen ore putting finishing touches an the cost-in-ponel windows. Far best appearonce, the structure should be pointed with white portlond cement point. The roof consists of 4 hyperbalic paraboloids--onother research project.



The completed building is shown. Windows were cast in the panels before erection. The door is 8 feet wide. Narrower doors could be used in pairs on alternate walls. This building is constructed of panels from various stages of the development and contains a number of experimental variables for weathering evaluation.

Growth Through Agricultural Progress